Forum invites authors to share their opinions on environmental issues with *EM* readers. Opinions expressed in Forum are those of the author(s), and do not reflect official A&WMA policy. *EM* encourages your participation by either responding directly to this Forum or addressing another issue of interest to you.

The Case for Improving Emission Inventories in North America

by William Pennell and David Mobley

Emission inventories are the foundation of effective air quality management. Although current inventories capably support today's emission management and regulatory activities, they have shortcomings. If these shortcomings are not addressed, they will compromise our ability to deal effectively with the air quality management problems of the future.

In the past, most air quality management goals have focused on emissions from major, and relatively well characterized, source categories. As recently implemented regulatory programs take effect, however, emissions from these sources will decline substantially. The remaining emissions will be more evenly distributed across source categories that are considerably more difficult to measure or model. Emissions from these source categories will also be growing as both population and economic activity increase. In this situation, errors in emission estimates from smaller individual sources will have greater consequences. These consequences could range from wrongly identifying a pollutant that should be controlled to overlooking source categories whose control could result in more cost-effective emission reductions.

William T. Pennell is the NARSTO Management Coordinator and a partner with Columbia Research and Education Associates, Pasco, WA. J. David Mobley is Associate Director of the U.S. Environmental Protection Agency's (EPA) Atmospheric Modeling Division in the National Exposure Research Laboratory, Research Triangle Park, NC. *Support for the NARSTO Management Coordinator is provided by the Office of Science (BER), U.S. Department of Energy, Grant No. DE-FG02-06ER64170. Disclaimer: EPA has subjected this article to administrative and peer review and approved it for publication.* *E-mail: bill@craea.com.*

The example of Houston, TX, illustrates this problem (see sidebar opposite). It shows that the cost consequences of unreliable or incomplete emission information can be considerable. Incomplete or inaccurate information also limits the development of effective policies. Unreliable or incomplete information on sources of toxic air pollutants, for example, can lead to inaccurate assessments of exposure. Likewise, incomplete information on the chemical composition of fine particulate matter (PM) affects our ability to understand the health effects of airborne particles and to develop more effective control measures based on this understanding. The policy consequences of poor information on emissions, therefore, are actions that may be misplaced or ineffective in achieving the goal of protecting human health and welfare.

> The consequences of unreliable or incomplete emission information can be considerable.

In 2004, NARSTO undertook the task of examining the current state of North American emission inventories and offering suggestions for improving them. A public/private partnership among government, industry, and academe in Mexico, the United States, and Canada, NARSTO's mission is to coordinate and enhance policy-relevant scientific research and assessment that promotes the development of effective strategies for local, regional, and continental air

Consequences of Incomplete Emission Information


Houston, TX

Incomplete or unreliable emission information can have serious consequences, in terms of the cost and effectiveness of air pollution control strategies. The case of Houston, TX, is a good example. Houston is currently in nonattainment for the National Ambient Air Quality Standards for ozone. The state had to devise a strategy that would result in compliance with the Clean Air Act standards or face federal sanctions. Based on existing emission inventories, the state concluded that reducing nitrogen oxides (NO_x) emissions by 90% would be effective in meeting the standards. In 2000, a field experiment was conducted to examine the atmospheric chemistry of the Houston area and the emissions driving this chemistry. The study discovered sources of highly reactive volatile organic compounds (VOCs) that were not included in the existing inventory.[1,2] Revised emission estimates and new modeling showed that achieving the desired air quality improvements would require reductions in these VOCs, but only an 80% reduction in NO_x emissions. A NO_x-only strategy would not have been as effective as expected. It would also have been expensive to implement. Interest groups active in the decision process have asserted that 10 years after implementation, a 90% reduction in NO_x emissions would result in 65,000 fewer jobs and a US$9-billion smaller regional economy compared to a 79% NO_x reduction strategy that allowed emissions trading.[3] While this analysis did not account for the costs of VOC controls, even when they are included, the revised control strategy results in substantial annual cost savings. Clearly, obtaining accurate and complete emission estimates is very important.

quality management. The findings and recommendations from this undertaking were published recently in the report: *Improving Emission Inventories for Effective Air Quality Management Across North America: A NARSTO Assessment.*[4] The NARSTO assessment

- reviews many national, state or provincial, regional, local, and specialty inventories and provides information for accessing them;
- describes the methods used to generate emission inventories and discusses the strengths and weaknesses of these methods, as well as of the resulting inventories;
- directs considerable attention to methods for determining uncertainties in emission estimates and provides comparisons between emission estimates and independent measurements for key emission sectors; and
- suggests ways to improve future inventories, characterize their uncertainty, and improve the delivery of emission data to users.

STRENGTHS AND WEAKNESSES OF CURRENT INVENTORIES

Over the past 40 years, emission inventories in all three countries of North America have improved dramatically in terms of accuracy and completeness. Today, air quality managers have a good understanding of the emissions from major point sources and they have used this knowledge in developing effective actions for reducing them. Models for estimating emissions from mobile sources have been continuously improved. The importance of natural and biogenic emissions has been recognized and this knowledge has affected the design of air quality management strategies in regions where these emissions are significant. In Canada and the United States, emission inventories and models can provide quantitative estimates of emissions at national, state or provincial, and county (or their equivalent) levels for many source categories, and there is an improved understanding of the relative importance of various source categories to specific air quality problems. Air quality managers can use these inventories to track emission trends and evaluate the effectiveness of measures designed to reduce these emissions. In Mexico, emission inventories have been completed for the Valley of Mexico and the states bordering the United States. The first national inventory will be released in the near future.

Despite this progress, emission inventories in all three countries have significant weaknesses that will become increasingly important for future air quality management. Addressing these problems is the focus of the findings and recommendations of the NARSTO assessment:

- There are significant uncertainties in mobile source inventories, particularly regarding the speciation of VOCs, the magnitude of carbon monoxide emissions, and the temporal trend of NO_x emissions.
- Emissions for many important categories such as fine particulates and their precursors, biogenic

emissions, ammonia, fugitive emissions, open biomass burning, and many other area sources are uncertain and inadequately characterized. Emission estimates for air toxics are particularly uncertain since there are so many of these compounds, so many potential sources, and so little data for establishing emission factors or speciation profiles.

- Quality assurance and quality control procedures are not strictly applied in the development of most emission models and inventories, and the documentation of uncertainties and data sources in emission inventories is not adequate.
- Emission estimates are frequently based on a small number of emission measurements that may not be representative of real-world activity; accordingly, the precision and accuracy of estimates developed from these measurements are limited.
- The process for developing information on emissions with the kinds of spatial and temporal resolution needed for location-specific air quality modeling is problematic and a source of unquantified uncertainty in model results.
- Methods used to estimate emissions of individual chemical species in many emission models are out of date and produce estimates that are not reliable.
- Current emission inventories are not developed and updated in a timely manner.
- Differences in current emission inventories in the three countries create difficulties for jointly managing air quality.

ADDRESSING THE WEAKNESSES OF CURRENT INVENTORIES

Maintaining the current quality of emission inventories, while reducing or eliminating their weaknesses is crucial if we are to sustain the progress of the past 30 years in improving the air quality of North America. To achieve this goal, the NARSTO assessment offers eight recommendations, each of which are briefly discussed below. The first recommendation was judged to be the most critical. The others are of somewhat lower priority, but in some cases, they may also need to be addressed in the course of meeting the priority-one objectives.

1 Reduce uncertainties associated with emissions from key undercharacterized sources.

Comparisons of national emission inventories with ambient measurements and other independent measures indicate that emission inventories for certain source categories and pollutants are inadequately characterized and reported. Of particular concern are nonpoint sources, including onroad and offroad mobile sources, as well as fugitive emissions from industrial facilities, landfills, sewage disposal systems, and feedlots. Sources of VOCs, carbonaceous PM, ammonia, and hazardous air pollutants (HAPs) are also not well characterized. The highest priority for emission inventory improvement should be placed on these categories. Resources should be targeted to reduce the greatest sources of uncertainty and focused on those source categories (or individual sources and conditions within these categories) whose control will be most effective in reducing costs and health risks, while achieving air quality management goals.

2 Improve speciation estimates.

Contemporary air quality issues, such as PM and ozone nonattainment and the identification of HAP "hot spots," require detailed information about the species being emitted from sources. Contemporary emission inventories are weak in this regard. It is essential that existing source speciation profiles be updated and improved. In addition, the related activity data must be developed to estimate more accurately speciated emissions of PM and precursors, VOCs, and toxic air pollutants.

3 Improve existing emission inventory tools and develop new ones.

Technical advances in instrumentation and computation are enabling emission measurements and analyses that have previously been impractical. Examples of these innovations include portable emission measurement systems for direct measurement of emissions under real-world conditions and the application of various remote-sensing systems for measuring emissions or verifying emission estimates. Continuing development of these and other technologies is likely to improve emission inventory measurements and analyses. Funding agencies need to continue to support the development and application of new technologies for measurement of emissions and ambient concentrations of pollutants. Application of these technologies will assist the development of emission models that more accurately represent emissions from real sources in time and space.

4 Quantify and report uncertainty.

The emission inventories, processors, and models of Canada, the United States, and Mexico are poorly documented for uncertainties. As a result, the reliability of emission estimates cannot be quantified. Quantitative measures of uncertainty and variability must be a standard part of reported emission inventory data. The responsible agencies of all three countries need to develop specific guidance on how to prepare and report information on emission uncertainties.

5 Increase inventory compatibility and comparability.

Emission inventories are developed by different national, state or provincial, or local entities across North America. Although there have been substantial improvements in reporting national emission inventories in mutually consistent ways, further work is needed to make these diverse inventories more comparable across organizations, purposes, political boundaries, and time periods. Canada, the United States, and Mexico should define and implement standards for emission inventory structure, data documentation, and data reporting, which would facilitate management of air quality in all three countries and would be especially helpful in dealing with transborder issues.

REFERENCES

1. Reyerson, T.B., et al. Effect of Petrochemical Industrial Emissions of Reactive Alkenes and NO_x on Tropospheric Ozone Formation in Houston, Texas; *J. Geophys. Res.* **2003**, *103* (D8), 4249; doi:10.1029/2002JD003070.
2. Wert, B.P., et al. Signatures of Terminal Alkene Oxidation in Airborne Formaldehyde Measurements during TexAQS 2000; *J. Geophys. Res.* **2003**, *103* (D3), 4104; doi:10.1029/2002JD002502.
3. Tolley, G.; Smith, B. *Cleaning Up Houston's Act: An Economic Evaluation of Alternative Strategies*; Final Report to the Greater Houston Partnership, 2001; available on request from the Greater Houston Partnership at www.houston.org.
4. *Improving Emission Inventories for Effective Air Quality Management Across North America: A NARSTO Assessment*; NARSTO-05-001; NARSTO, 2005; available at www.narsto.org.
5. *Improving Emission Inventories for Effective Air Quality Management Across North America: A NARSTO Assessment; Chapter 9*; NARSTO-05-001; NARSTO, 2005.
6. *Final Report to Congress on Benefits and Costs of the Clean Air Act*; EPA-410-R-99-009; U.S. Environmental Protection Agency, Office of Air and Radiation, Washington, DC, 2001.

6 Improve user accessibility.

The accessibility of emission inventories and emission models is impeded by the sheer size of the files and the cumbersome manner in which the data are reported and archived. As improved accessibility to emission data is critical to meeting the diverse needs of the user community, increased efforts should be made to facilitate user accessibility to emission inventory data and models through the Internet and other electronic formats.

7 Improve timeliness.

Timely and historically consistent emission inventories are essential for assessing the current emission environment (and for keeping abreast of economic conditions and changes in technology) and for tracking progress in improving air quality. Plans and processes need to be put in place for preparing and reporting national emission inventory data on an annual basis.

8 Assess and improve emission projections.

Realistic projections of future emissions are important for developing and assessing strategies for attaining air quality standards (e.g., the Regional Haze Rule) and for evaluating future-year effects of new regulations. Emission projection methodologies for all emission inventory sectors in North America should be evaluated to determine the accuracy of past projections and to identify areas for improvement. Attention should be paid to assuring the compatibility of short-range projections that are more typical of air quality-related emissions with the long-range projections that are made for climate change applications. Projections of future emissions are also dependent on the quality of the base-year emissions. Therefore, realistic projections cannot be made unless the improvements called for in this article are implemented.

IMPLEMENTATION OF RECOMMENDATIONS

Implementation of these recommendations over the next 10 years is essential if we are to develop the kinds of emission information needed for meeting future air quality challenges. However, implementing these recommendations will not be easy in the current budgetary environment. Obtaining the emission inventories will require creative collaboration among all stakeholders, both public and private. Progress on the continental scale will call for continued, and probably enhanced, cooperation among Canada, the United States, and Mexico. It will require individual actions by the national regulatory agencies to assist state, local, and provincial agencies in meeting their inventory development responsibilities. It will require investments in educating the next generation of emission scientists and engineers and in the tools needed to construct future emission inventories.

Specific implementation plans will need to be developed for each country of North America, as each has different air quality management priorities and each is at a different stage in its national emission inventory development program. Even within each country, there will be different local and regional priorities. To initiate the planning process, the authors of the NARSTO assessment developed a set of country-specific "initial action plans" that should be taken over the next three to five years to meet the 10-year goals of the assessment. These actions would require approximately a doubling of the investment in emission inventories in Canada and the United States and an order-of-magnitude increase in Mexico.[5]

Although details in implementation will differ among the countries of North America, four common actions are recommended to all:

1. Implementation efforts should be planned, coordinated, and executed by Environment Canada, the U.S. Environmental Protection Agency, and Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) over the next 10 years. Interim milestones for emission inventory improvement should be developed to support regulatory deadlines in each country.
2. Federal support for regional, state, and provincial emission inventory development and improvement needs to be ongoing to ensure that emission inventories are able to provide the required quality of information.
3. Interaction and collaboration among and across Canada, the United States, and Mexico should be maintained and enhanced.
4. Increased training of industrial stakeholders and agency staff at federal, state and provincial, and local levels will be required to effectively implement this work.

CONCLUSIONS

Current spending on emission inventories is roughly US$40 million per year for Canada, the United States, and Mexico.[6] This is obviously a substantial sum. To put this sum into perspective, it has been estimated that the United States spent approximately US$19 billion in 1999 to meet the requirements of the Clean Air Act.[5] Thus, for every US$1000 spent to meet Clean Air Act requirements in the United States, approximately US$2 is spent to characterize emissions. Doubling this investment would significantly improve knowledge of emissions and the ability to design better-targeted air quality management strategies. Better-targeted strategies, in turn, should reduce the cost of regulatory compliance. A modest increase in expenditures on inventories, therefore, should lead to far more cost-effective protection of our health and ecosystems. em